PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Anchoring Systems

We, CALIFORNIA RESEARCH CORPORATION, a corporation duly organized under the laws of the State of Delaware, United States of America, and having offices at 200 Bush Street, San Francisco 4, California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to structures for drilling wells in offshore locations and, more particularly, to means for anchoring such structures in a fixed location by apparatus which will hold the structure relatively stationary against the wind and water forces normally encountered at offshore drilling sites, but will permit a predetermined controlled oscillation when the structure is exposed to excessive forces to thereby control the stresses placed on the structure and on the anchoring apparatus.

As offshore drilling progresses into deeper waters, the problems involved in erecting a marine structure to hold the drilling platform and anchoring it in a stationary position at the drilling site become increasingly more severe, and the cost of such structures rises accordingly. Of the several methods which have been employed or proposed heretofore for offshore drilling, those that require a structure to be anchored in a fixed position relative to the bottom of the water by an anchoring system which is, for the most part, external or auxiliary to the structure itself are of particular pertinence for the purposes of the present invention. Such a drilling structure may, for instance, comprise a drilling platform supported on submerged buoyant members and held in position at the well site by anchor lines extending to fixed anchors at the ocean bottom. Another such structure may comprise a slender column or mast which is seated at its bottom end on the ocean floor and extends vertically through the water to support a drilling platform above its surface. The latter structure is held in a vertical position primarily by anchor or guy lines which extend downwardly and outwardly from the top portion of the column to a fixed anchoring means at the bottom of the water. In this case, the anchor or guy lines become component parts of the support structure and act as tensile members which restrain the column from being displaced from a vertical position by the transversely directed wind and water forces acting on it, especially those forces acting on its uppermost portions.

An effective anchoring system for a deep water drilling structure must be capable of restraining the structure from excessive movement induced by the action of the several separate wind and water forces which act on it simultaneously. One of these, obviously, is the periodic wave motion of the water surface. However, this motion by itself would not be too significant under ordinary fair weather conditions. For instance, with a freely floating structure such as a barge, or a boat, the structure would have approximately the same amplitude of motion about a central point as would a particle of water· Thus, if the water surface was disturbed only by periodic six-foot waves, a particle of water on the surface would have an orbital motion of approximately six-foot total amplitude, and a freely floating structure would follow the motion of the water particle. This oscillation of the drilling structure would not be too significant in deep water drilling, provided the period of oscillation was that normally encountered with ocean waves.

Of more significance, perhaps, under normal conditions are the effects of wind and water forces which constantly bear on the drilling structure from a transverse or lateral direction. A tidal current, for instance,

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would soon carry a floating drilling structure far off the drilling site if it was not anchored in place, or cant a column from a vertical position if it was not restrained by anchor lines. Therefore, in order to maintain a structure in position over the well site, it is necessary to anchor it there.

The anchors, while necessary, inherently produce a complication in that they, together with the structure they restrain from movement, form an elastic system which is susceptible to forced vibrations under periodically applied forces. The resonant frequency of this system can be within the frequency of wave motions ordinarily encountered in ocean waters, and this phenomenon has been experienced on anchored ships. As applied to a drilling structure, if an attempt is made to solve this problem by slacking off the anchor lines, the structure is given enough leeway to move off the drilling site. This is, of course, objectionable, and if the drilling platform is permitted to migrate too far from its position above the well bore, the equipment connecting the drilling platform with the well bore will be damaged or destroyed. Obviously, also, slacking off the anchor lines of a slender column would permit it to tilt at an angle from the vertical and make drilling from the drilling platform it supports impossible.

If an attempt is made to change the vibration characteristics of the system by tightening up on the anchor lines, the elastic system becomes resonant at a higher frequency and hence more susceptible to forced oscillation by the smaller water waves of higher frequency. Furthermore, such a procedure places a greater stress on the anchor lines and puts more force on the anchors, necessitating the use of heavier equipment. The cost of a lateral anchoring system is almost proportional to its holding capacity, and, other considerations aside, it becomes economically unattractive to make an anchoring system strong enough to withstand directly all of the forces imposed on the drilling structure, including that of forced oscillation, to hold it stationary in place under all of the conditions of wind and water forces it is likely to encounter.

It is an object of this invention to provide a novel anchoring system for an offshore drilling structure to hold the structure relatively stationary in place at the drilling site during normal conditions of wind and water and permit it to move with a controlled oscillation when abnormally severe wind and water forces are imposed on it.

A further object of this invention is to provide a novel anchoring system for an offshore drilling structure which automatically will control the stresses placed in the anchoring lines to hold them below a predetermined maximum amount.

Another object of this invention is to provide anchoring means which are operatively integrated with a marine structure to make in combination with the structure a system having lateral force-deflection characteristics which limit the amplitude of lateral oscillation of the structure and the forces induced in the anchoring means.

Other objects of this invention will become apparent as the description of it proceeds in conjunction with the accompanying drawings which form a part of this application.

The objects of this invention are achieved by providing a marine structure with an anchoring system which comprises buoyed anchor lines extending substantially as straight lines radially from the structure and diagonally downward to anchors at the bottom of the water. The anchor lines are placed under sufficient tensile stress between the anchors and the structure so that they will act as rigid tensile members as distinguished from catenary members.

The upper ends of the anchor lines are mounted over the pulleys or some similar means supported by the column structure and then are operatively connected to loading means, which in a simple form may be counterweights, which will prevent the tensile stress in the anchor lines from exceeding a predetermined maximum value. When the transverse periodic forces imposed on the drilling structure exceed that for which the anchor lines are designed, as may be the case when the structure moves under a forced vibration, the anchor lines are able to move over their pulley mounts, and the loading means attached to them will hold them below their designed maximum tension while the drilling structure tends to oscillate. The inertia forces resulting from the movement of the structure help to resist the wave forces so that the forces to be resisted by the anchor lines are substantially lessened.

The loading means is selected to act together with the anchor lines to place a resultant anchoring force on the drilling structure sufficient to hold it substantially stationary under normal operation conditions. Under these conditions the anchor lines will function as if they were rigidly attached to the drilling structure, and the elastic system which comprises the structure and the anchoring means will have definite resonant frequencies. However, if a forced vibration builds up in the system and tends to produce an oscillation of magnified amplitude, the anchor lines will move on their pulley mounts, and the maximum load which will be imposed on them will be substantially that applied by the loading means. This will cause the resonance characteristics of the system to change abruptly. The system then will be out of resonance with the periodically applied forces which caused the vibration,

and hence the vibration will not increase substantially in amplitude.

The anchoring system, including the buoyed anchor lines, the bottom anchors to which they are attached, and the loading means which holds them in tension, is designed to anchor the marine structure at the desired location under all foreseeable wind and water conditions. This does not mean, however, that it is intended to hold a drilling structure, for instance, rigidly stable under storm conditions against the tremendous forces imposed on it, nor is it anticipated that conditions on the drilling platform during a storm will be sufficiently quiescent to permit normal drilling procedures to be pursued. However, the system is designed to hold the structure at the drilling location without damage to any of its component parts, and to do so with less massive equipment than would be required with ordinary anchoring means.

Several embodiments of the anchoring system of this invention are illustrated in the accompanying drawings in which:

Fig. 1 is a schematic representation of a column structure supporting a drilling platform above the surface of the water and anchored in position by an anchoring system of this invention.

Fig. 2 is a schematic representation of a side elevation of a modification of the anchoring system applied to a marine column structure with parts broken away to present an illustration of the arrangement of some of the components of the system.

Fig. 3 represents a plan view taken along line 3-3 of Fig. 2.

Fig 4 is a schematic representation of the sheave arrangement through which the upper ends of the anchor lines are connected to loading means.

Fig. 5 is a graphical illustration of the relationship between force and displacement in an anchoring system of this invention.

Fig. 6 represents a side elevation of another modification of the anchoring system as applied to a marine column structure with parts broken away to better illustrate the interrelationship of the components.

Fig. 7 is a plan view taken along the line 7-7 of Fig. 6 and illustrates the arrangement of the counterweights in this modification of the invention.

Fig. 8 is a plan view taken along the line 8-8 of Fig. 6 and illustrates further details of the arrangement of the pulley system on the column.

Fig. 9 represents in side elevation another modification of an anchoring system in accordance with this invention with parts broken away to better illustrate the interrelationship of the components.

Fig. 10 is a plan view taken along the line 10-10 of Fig. 9 of a portion of this embodiment of the anchoring system.

Fig. 11 is a schematic representation of a loading means for the anchor lines employed in the modification of the invention illustrated in Fig. 9

Fig. 12 represents a schematic illustration of the anchoring system as applied to a floating drilling platform.

As illustrated in Fig. 1, a drilling platform 20 is supported above the surface of the water 22 by a column structure 24, the lower end of which is seated at the bottom of the water 26 in a footing 28 which holds the bottom of the column at the drill site. Drilling structures of this type are intended for use primarily in relatively deep waters in the range of depth, for instance, from 350 to above 1,000 feet.

The support column is a slender structure, and may have a ratio of length to diameter in the order of from 20-1 to 40-1. As will be understood in the art, such a structure may be built on land with buoyancy chambers incorporated in it so that it may be floated in a horizontal position to the drilling site. The column is placed in a vertical position by flooding the buoyancy chambers in its lower portion while maintaining those in its upper portion filled with air. The column is then towed to a position over the drilling site, and its buoyancy is controlled to permit it to sink in a vertical position until its bottom footing is seated on the submerged earth. The chambers in the lower portion of the column may then be filled with a dense material, such as sand or cement, to hold it firmly seated on the bottom while the upper chambers remain buoyant. Such a manipulation of the buoyancy chambers not only assists in maintaining the column in a vertical position but also produces a tensile stress through the middle portion of the column, thus increasing its load carrying ability.

As illustrated in Figs. 2 and 3, the column is constructed to include as load carrying structural members the plurality of conductor casings 30, through which the drill string will be guided to drill wells in the submerged subterranean formations. The conductor casings are trussed together as indicated by the numeral 32 and may have an exterior shell 34 and an interior shell 36 connected to them. The shells also may be load-carrying members, and they, together with the conductor casings and the interconnecting trussing, form a rigid column. The column may be partitioned along its longitudinal axis by a plurality of transverse walls, such as are indicated by the numerals 38 and 40, which are sealed to the shells and the conductor casings in a fluid-tight manner to form separate buoyancy chambers along its length. Such a construction produces a column which has sufficient stiffness to support the weight of the drilling platform,

including the derrick 42 and the equipment necessary for drilling the well, which are mounted on the top of the column after it is anchored in place.

After the column is set on the bottom at the drill site and before the drilling platform structure is erected on the top of it, it is anchored in place against transverse or lateral forces imposed on it by wind and water action by a plurality of anchor lines 44. These lines are spaced circumferentially around the column and extend diagonally downwardly and outwardly to corresponding anchoring means 46 which are positioned at the bottom of the water in horizontally spaced relationship to the bottom of the column and angularly spaced from each other to be properly disposed to hold the respective anchor lines in the desired position. The anchor means 46 may be a massive weight lowered through the water from a derrick barge to a position on the water bottom which has been determined beforehand to be the proper position with respect to the location of the column to produce the best anchoring effect. In the present invention the particular arrangement of the anchor lines and the manner in which they are mounted on the column structure permits the use of a less massive anchoring system than would be necessary if the anchor lines were secured in a fixed relationship to the column and anchors.

Pursuant to this invention the anchor lines 44 are buoyed along their lengths so that they will assume a substantially straight line position between the bottom anchors and their mountings on the column when they are placed in tension. For example, neutrally buoyant anchor lines may be used of interconnected sections of steel tubing with each section hermetically sealed and properly weighted to have a density substantially equivalent to that of the water at the depth at which a particular section will be positioned when the anchor line is assembled between the bottom anchor and the column. Alternatively, the anchor line may be a continuous metal tube sealed at its ends to form a buoyant chamber and having a wall thickness varying with depth to achieve substantially neutral buoyancy throughout its length. For some installations it may be desirable to use a steel cable surrounded by a covering of buoyant material to form a neutrally buoyant anchor line, or the anchor lines may be buoyed at spaced intervals along their length to achieve the effect of neutral buoyancy.

Preferably the anchor means 46 are placed in position on the bottom surrounding the well site prior to the time the column structure is put in place. The anchor mass has projections 48 extending from the bottom of it which penetrate into the earth formations at the bottom of the water and improve the gripping ability of the anchor. It will be appreciated that the anchor may be made to include a chamber which can be filled with a substance of less density than water, such as air, gasoline, or the like, to make the anchor buoyant so that it may be towed into position on the surface of the water and then sunk by flooding the chamber. Finally, in this case, the chamber may be filled with sand or some other heavy material to give the anchor maximum weight on the bottom. Such an anchor construction permits recovery of the anchor and attached anchor line by removing the weighting material and floating the anchor to the surface.

It is desirable to attach the lower end 50 of a respective anchor line to the anchor means, such as by an eye connection 52, prior to lowering it through the water. The free end of the anchor line is attached to a buoy which will ride on the surface of the water. When all of the anchors and anchor lines are placed in their respective positions around the well site, the column structure 24 is manoeuvred into position and seated on bottom at the well site, and the anchor lines connected to it. The positive buoyancy of the upper portion of the column structure will hold the column vertical while the anchor line connections are being made.

As best illustrated in Figs. 2 and 3, this modification of the invention employs six anchor lines which are distributed in equiangular relationship around the column structure. The upper portion of each anchor line is mounted on a respective pulley 54 affixed to the exterior of the top portion of the column structure and continues over a series of pulleys or sheaves 56 and 58 to the interior of the column structure, where its end 60 is connected to a loading means such as a counterweight 62. The anchor lines act in pairs so that single anchor lines such as 64 and 66 which are disposed on opposite sides of the column are connected to the same counterweight. Thus, for the arrangement illustrated in Figs. 2 and 3, the six anchor lines form three pairs, each of which is connected to a separate counterweight. The counterweights are free to move upwardly and downwardly parallel to the longitudinal axis of the column and may be restrained to a particular vertical path by track means 70, as illustrated in Fig. 3. A stop means 71 is affixed to the column structure immediately below the equilibrium position of the counterweights to support the load of a counterweight if one of the anchor lines of the pair atached to it should fall or a bottom anchor 46 suddenly slip and cause its attached anchor line to go slack. In such a circumstance the stop means prevents the full load of the counterweight from being placed on the other anchor line of the pair.

The mass of the counterweights is selected to hold the anchor lines under tension and produce a resultant force at the pulley mounts 54 to hold the column stationary in place against any transverse force which normally will be imposed upon it by the action of the wind and the water. For example, a column designed for use in 500 feet of water may have a diameter of approximately 28 feet. To hold this column stationary against normally occurring transverse forces, a counterweight weighing 600,000 pounds may be required for each pair of anchor lines. Thus, with the column in an equilibrium position, the counterweight will apply a tensile force of approximately 300,000 pounds to each anchor line, and this anchoring force will be sufficient to hold the column relatively stationary against normal wave action.

In storm conditions, where 50-foot waves can be expected, the transverse or lateral forces imposed on the column structure may be as great as several millions of pounds and thus greatly exceed the several hundred thousand pounds which occur during normal wave conditions. If the anchor lines were rigidly attached to the structure under these conditions, they would, unless they were massive enough to sustain the greatly increased tensile forces, either part or pull the bottom anchors loose, and the structure would be destroyed.

However, in accordance with this invention the maximum tensile force which can be placed on an anchor line is governed primarily by the counterweight, and hence the tension in the line cannot exceed the designed limits. If, for example, the column structure shown in Fig. 2 had a transverse force imposed on it which caused it to move to the right of the figure in the direction of arrow A, the tension would be increased in the anchor line 66 on the side of the structure opposite to the direction of the movement, and this line would lift the counterweight from its equilibrium position. The counterweight would then impose a tensile force of 600,000 pounds in this anchor line, and hence the anchor line would impose a constant restoring force of approximately 600,000 pounds on the top portion of the column structure to oppose the displacement caused by the transverse force. At the same time the complementary anchor line 64 disposed on the side of the column in the direction of the transverse movement would have the mass of the counterweight removed from it and hence would go slack. Thus there would be no tension in this anchor line to add to the transverse force which caused the movement of the column.

It will be appreciated that the storm waves are periodic in nature and may have periods in the range of 11 to 15 seconds, for instance, for 50-foot waves. Thus, as the wave passes the column and its peak force diminishes, the constantly acting restoring force of the counterweighted anchor lines together with the positive buoyancy of the upper portion of the column will move the structure back to its vertical position. The limited movement of the structure is sufficient to develop an inertia force which resists the greater portion of the wave force on the column.

It will be apparent from the arrangement of the anchor lines shown in Figs. 1 to 3 that a sufficient transverse movement of the column structure will place at least two single anchor lines of different pairs under sufficient tension to lift their connected counterweights, and in most cases three of the anchor lines will be restraining the structure with a constant restoring force. Obviously the counterweights are constructed and placed in the column to permit their vertical rise and fall within the design limits of anticipated amplitude of movement of the structure.

In the assemblage illustrated in Fig. 1, as explained heretofore the buoyed anchor lines 44 extend as straight lines between the bottom anchors and their mounting on the column and normally are operating under tension. The column itself, although rigid enough to support the drilling structure mounted on its top, is susceptible to some flexure under transverse forces. The combination of the column, the supported drilling structure, and the anchor lines forms an elastic system which inherently will have particular vibration characteristics.

Transverse forces of two kinds normally will be imposed on the structure. These comprise, in one group, such transverse forces as those induced by the wind or a current of water, or eccentric loading on the drilling platform, which act on the structure from a single direction for a relatively long period of time, and in another group, periodic wave forces. Under normal operating conditions the periodic wave forces will cause the system to oscillate. If the anchor lines were rigidly attached to the structure, as has been suggested in prior art, the forced vibration under resonant conditions can build up in magnitude to a degree to impose forces on the system greater than its designed limits. When such systems are at or near resonance the phase relations are such that the inertia forces of the oscillating mass add to the applied wave forces so that the total periodic force on the anchor system can substantially exceed the applied wave force. As a result the system may fail.

Fig. 5 is a graphical illustration of the force-displacement relationship of a simple elastic system as compared with the force-limiting system achieved by means of the present invention. The relationship will be described for a displacement of the system in one direction from equilibrium.

In the elastic anchoring system described

immediately heretofore, in which the neutrally buoyant anchor lines are attached in a fixed connection to the column and to the bottom anchors, the anchor lines act as tensile springs, and the force-displacement characteristic has a straight-line relationship as indicated by the line A-C. In such a system, as the top portion of the column tends to be displaced by transverse forces imposed on it, the force in the anchor lines builds up proportionately. These transverse forces may be increased by a resonant vibration of the column-and-anchor system under periodic wave forces. Under these conditions the forced vibrations set up in the system may produce forces on the anchors that are far greater than the applied wave forces.

The line A-B-D of Fig. 5 illustrates the force-displacement relationship of the force-limiting system of the present invention. As has been noted heretofore, the anchor lines are disposed substantially as straight lines between the bottom anchors and the pulley system on the column. The loading on the ends of the anchor lines causes a resultant force at the pulley supports 54 which has a component directed radially outwardly relative to the column and will hold the column relatively stationary under applied transverse loading below a predetermined amount. When this predetermined amount is not exceeded, the anchor lines will act as tensile springs, and transverse loading on the column will cause the anchor lines to stretch in a straight-line force-displacement relationship as indicated by the line A-B. When the transverse loading on the column exceeds the force corresponding to point B of the graph, the anchor lines under the greatest tension will move in their respective pulley mounts and lift the counterweights attached to their ends. The lifted counterweights impose a constant load on the anchor lines, rather than a continuously increasing load, and hence the force-displacement relationship of the elastic system changes and assumes the characteristic indicated by the line B-D of the graph. It will be noted, therefore, that the vibration characteristics of this system change abruptly when a lateral force above the predetermined amount is placed on the structure. When lateral vibrations start to build up from periodic forces synchronous with the natural frequency of the elastic system the vibration characteristics of the system change at the point B, and it is no longer in synchronism with the periodic forces which induced the vibration. Hence the amplitude of the forced vibration is substantially limited to that associated with a periodic force corresponding to the point B. Thus, by the system of the present invention the anchor lines and bottom anchors used can have a capacity less than that which would be required by a rigidly connected, or purely elastic, anchoring system and still maintain the drilling structure at the well site without structural damage when it is exposed to the large wave forces produced by storm conditions.

The schematic pulley system of Fig. 4 illustrates how the plurality of single anchor lines may be mounted on the upper portion of the column and connected to their respective counterweights. As described heretofore, the anchor lines 64 and 66 which are disposed on opposite sides of the column as indicated in Fig. 3 act together as one pair. The anchor line 64, after passing over the initial pulley 54 attached to the exterior of the column, is passed over the pulleys 56 and 58 and thence downwardly within the interior of the column and attached to the counterweight 62. The complementary anchor line 66 of the pair likewise is initially mounted on a respective fixed pulley 54 and thence is passed over the pulleys 72 and 74 to the interior of the column, where it is connected to the same counterweight 62. In a like manner, the complementary anchor lines 76 and 78 are passed through respective pulley systems mounted on the column, and each connected to a common counterweight 80. The anchor lines 82 and 84 also are each mounted on a respective similar pulley system and connected to the common counterweight 86. The pulley systems 88, 90 and 92 corresponding to individual pairs of anchor lines are displaced in vertical position along the column structure to provide clearance for the various pulley-and-line systems within the structure.

Figs. 6, 7 and 8 illustrate another embodiment of this invention as applied to a column structure, and the same reference numerals as used heretofore will be employed to indicate similar components. As shown in Figs. 6 and 8, six anchor lines 44 are disposed in equiangular relationship around the column 24 and are connected to bottom anchors, not shown. The upper portions of the anchor lines are mounted on respective pulleys 94, and the ends of the lines are attached to counterweights 96 and 98. In this modification of the invention three oppositely disposed anchor lines, such as 100, 102 and 104, are attached to a common counterweight 96. The other three lines 106, 108 and 110 also are attached to a separate common counterweight 98. The counterweights 96 and 98 are disposed on the outside of the column structure and may conveniently take the form of cylinders which are concentric with it and with each other.

The pulleys 94 on which the upper ends of the anchor lines are mounted are supported on the column so that they can be adjusted individually in vertical position. As indicated in Fig. 6, the pulley 94 is rotatably mounted in a bracket structure 112 which is

affixed to a base member 114. The base member is restrained in circumferential position by track ways 116 and 118 which are affixed to the outer shell 34 of the column and disposed to permit the pulley assembly to be raised or lowered. The base member 114 is attached by an eye connection 120 to a cable 122 which passes over a respective sheave 124 on the drilling platform 20 and thence to a winch 126 which supplies the power for adjusting the position of the pulley assembly. Thus the vertical location of a respective pulley 94 can be adjusted to take up slack or relieve tension in the particular anchor lines associated with it. This permits an adjustment of the anchoring system to put equal tension in all of the individual anchor lines when the column is in an equilibrium condition. It also permits the individual adjustment of the tension in any one line if the line goes slack because the bottom anchor associated with it slips or creeps. A stop means 127 is affixed to the outside of the column immediately below the counterweights to support the load of a counterweight if a line attached to it should fail.

The vibration characteristics of the anchoring system shown in this modification are similar to those for the modification explained heretofore. The anchor lines 44 will act as if they were fixedly connected to the column when the latter is exposed to transverse forces below a predetermined amount. Thus through this range of operation the force-displacement relationship will be due primarily to the tensile stretch of the anchor lines, and vary as a straight line as indicated by the line A-B of Fig. 5 described heretofore. When the transverse forces on the column exceed this predetermined amount, the anchor lines under greatest tension will raise the counterweights attached to them, and thus the tension in the anchor lines will be limited substantially to the amount imposed by the loading of the counterweights. It will be observed from the arrangement of Fig. 8 that a movement of the column structure in any transverse or lateral direction will place at least two adjacent anchor lines under increased tension, and hence the restoring force of this anchoring system will be effected through the action of both counterweights, assisted by the buoyancy of the upper portion of the column structure.

The modification of the invention shown in Figs. 9, 10 and 11 employs a piston-and-cylinder arrangement as a loading means for the anchor lines. The column structure of this modification is similar to that described heretofore and the same reference numerals will be used to indicate comparable components. The anchor lines 128 and 130 are mounted over pulleys 54 affixed to the column, and the ends of them are passed over respective pulley systems 88, 90 and 92 in the manner described heretofore with reference to Fig. 4. The single anchor lines disposed on opposite sides of the column structure form a pair which is connected to a common loading means in a manner similar to that described with relation to Figs. 2 and 3. The loading means in this modification comprises a pneumatic cylinder 132 within which the piston 134 is operatively mounted. The piston rod 136 passes through a packing gland 138 and is connected, as by an eye connection 140, to the complementary anchor lines, as 128 and 130, of a respective pair. The cylinders are fixed in position within the column structure as by brackets 142.

In the modification of the invention illustrated, six anchor lines are disposed around the column structure, and hence the oppositely disposed, interconnected anchor lines will form three pairs, each of which is connected to a corresponding similar loading means. The pneumatic cylinders are manifolded together, as by a conduit 144 which is connected to an air accumulator 146 on the drilling platform through the conduit 148. The compressor 150 supplies the accumulator and the pneumatic cylinders with air at a constant predetermined pressure which may, for example, be 1,000 pounds per square inch. Thus the pistons place an initial predetermined tension in the anchor lines, sufficient to hold the column structure relatively stationary under normal operating conditions. If the column structure is moved by a transverse force, the anchor lines under greatest tension will raise the pistons associated with them, and the tension on the anchor lines will thus automatically be limited.

It is desirable in this modification of the invention that the pneumatic loading means act on the anchor lines with a substantially constant force in a manner similar to the counterweight arrangements described heretofore. This may be accomplished by making the cylinder 132 of large capacity relative to the maximum displacement of the piston, so that the air pressure within the cylinder will not build up appreciably as the piston is raised. This effect is aided by manifolding the cylinders together and connecting them to the air accumulator, since the capacity of these interconnected parts forms a relatively large reservoir to receive the air placed under increased pressure by the action of the anchor lines on the respective pistons. The force-displacement relationship for this system will therefore be similar to that illustrated in Fig. 5 and explained heretofore.

It will be appreciated that the illustrated embodiments of the invention are merely indicative of loading means which can be used in the anchoring system of this invention and that other loading means which produce a similar reaction in the anchor lines may be employed in their place.

Fig. 12 illustrates the anchoring system of this invention applied to a floating drilling platform. This structure comprises a drilling platform 152 which is mounted through appropriate structural members 154 on pontoons 158 and 160. The pontoons are positively buoyant and are pulled below the surface of the water and held there by a plurality of lines 162 which are attached to corresponding anchors 164 on the bottom. The pontoons are thus maintained in position below the water surface and out of the environment of the forces occuring at the water surface. The structure is restrained in position over the drill site by anchoring it to a plurality of laterally disposed anchors, all of which is familiar in the art.

The anchoring system of this invention is applied to such a structure in a manner similar to that explained heretofore for the column structure. A plurality of buoyed anchor lines 166 extends from corresponding fixed bottom anchors 168 to respective pulleys 170 which may be mounted on the pontoons and thence are passed over a pulley system, indicated by the pulley 172, to counterweights 174 which are supported in a guide housing 176 affixed to the respective pontoons. Oppositely disposed anchor lines, such as 178 and 180, for example, are arranged to act as a pair by connecting them to a common counterweight 174. As explained heretofore, the anchoring system will contain a number of similar counterweight arrangements corresponding to the number of pairs of anchor lines. Thus in the illustrated system, eight laterally disposed anchor lines are grouped in four pairs, each of which is connected to a respective counterweight.

The characteristics of the elastic system formed by the floating drilling platform and the associated anchor means are similar to those described heretofore for the column structure. The counterweights 174 will place sufficient tension in the anchor lines 166 to hold the structure relatively stable under ordinary working conditions, but will permit it to move with a controlled tension in the anchor line when exposed to excessive transverse forces. The anchor lines place a restoring force of constant amount on the drilling platform when it is displaced from its equilibrium position, and the movements of the counterweights modify the elastic characteristics of the system to make it nonresonant when forced vibration produces deflections that would otherwise stress the anchor lines above the predetermined designed limits.

It is apparent that many modifications can be made and equivalents substituted for the various components of the anchoring systems illustrated herein. Therefore, it is desired that the described exemplary embodiments of this invention be accepted as illustrative and not limiting and that the scope of the invention be limited only by the definition of the appended claims.

WHAT WE CLAIM IS:—

1. An anchoring system for an offshore marine structure, said system comprising a plurality of buoyed anchor lines extending outwardly from the marine structure as substantially straight lines, one end of each of said anchor lines being affixed to anchor means for each corresponding line on the sea bottom and the other end of each of said anchor lines being mounted on the marine structure in such a manner as to permit movement of the structure relative to the anchor lines in a direction transverse to the vertical axis of the structure, said other end of each of the anchor lines being connected to means for automatically maintaining a substantially constant predetermined maximum tension in the anchor lines when the marine structure moves relative to the anchor lines.

2. An anchoring system according to Claim 1, wherein the marine structure comprises a substantially vertical column the lower end of which is seated on the sea bottom and the upper end of which extends above the surface of the water to support a drilling platform above said surface.

3. An anchoring system according to Claim 2, wherein the anchor lines are distributed in equiangular relationship around the column.

4. An anchoring system according to Claim 3, wherein said other ends of the anchor lines are mounted on a plurality of pulley systems and are connected to a plurality of loading means disposed within said column.

5. An anchoring system according to Claim 4, wherein each pair of anchor lines constituted by single lines disposed on opposite sides of the column is connected to a corresponding loading means.

6. An anchoring system according to Claim 5, wherein the loading means is a counterweight.

7. An anchoring system according to Claim 5, wherein the loading means is a pneumatic cylinder and piston.

8. An anchoring system according to Claim 3, wherein said other ends of the anchor lines are mounted on a plurality of pulley systems and are connected to a plurality of loading means disposed on the exterior of said column.

9. An anchoring system according to Claim 8, wherein the loading means comprises a cylinder concentric with said column.

10. An anchoring system according to Claim 9, wherein alternate anchor lines are connected to a first concentric cylinder and the remaining anchor lines are connected to a second cylinder concentric with said first

cylinder and with the column.

11. An anchoring system according to Claim 1, wherein the marine structure comprises a drilling platform supported on submerged buoyant members and held in position by anchor lines extending substantially vertically to fixed anchors at the sea bottom.

12. An anchoring system according to Claim 11, wherein each individual anchor line of a pair of anchor lines constituted by two lines laterally disposed on opposite sides of the structure passes over a pulley system and is connected to a corresponding loading means for each pair of lines.

13. An anchoring system for an offshore marine structure, substantially as hereinbefore described with reference to, and as shown in, Figures 1, 2, 3 and 4 of the accompanying drawings.

14. An anchoring system for an offshore marine structure, substantially as hereinbefore described with reference to, and as shown in, Figures 6, 7 and 8 of the accompanying drawings.

15. An anchoring system for an offshore marine structure, substantially as hereinbefore described with reference to, and as shown in, Figures 9, 10 and 11 of the accompanying drawings.

16. An anchoring system for an offshore marine structure, substantially as hereinbefore described with reference to, and as shown in, Figure 12 of the accompanying drawings.

HASELTINE, LAKE & CO.,
28 Southampton Buildings, London, W.C.2.
Agents for the Applicants.

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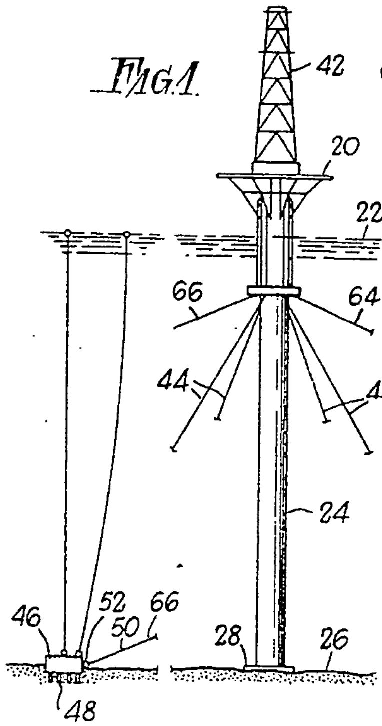

FIG. 1.

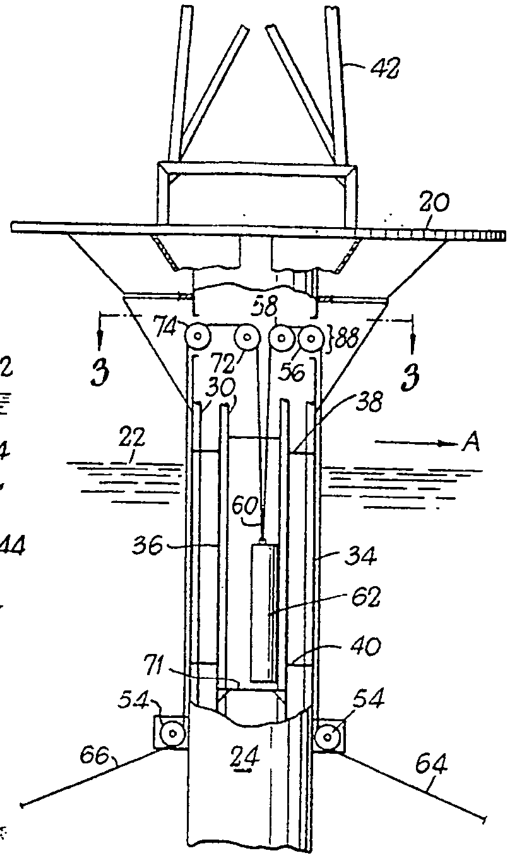

FIG. 2.

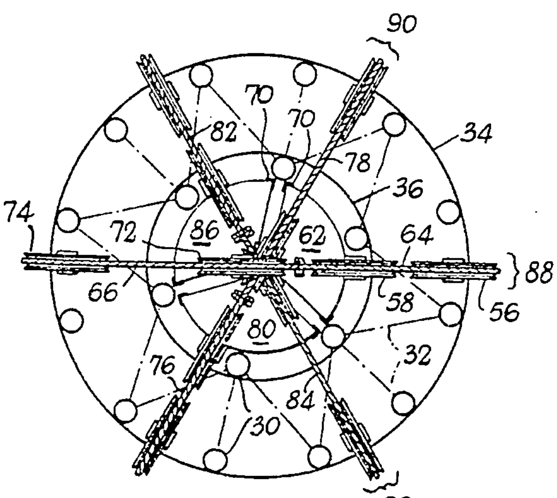

FIG. 3.

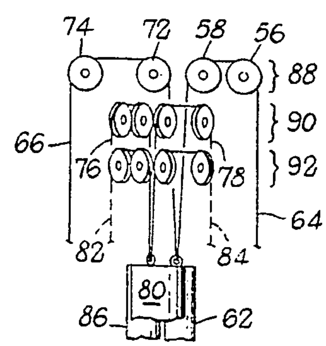

FIG. 4.

849,887 COMPLETE SPECIFICATION
4 SHEETS
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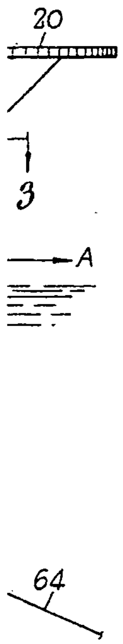
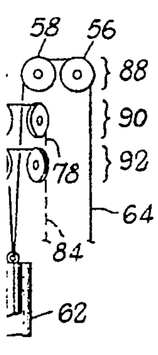
SHEETS 1 & 2





r.4

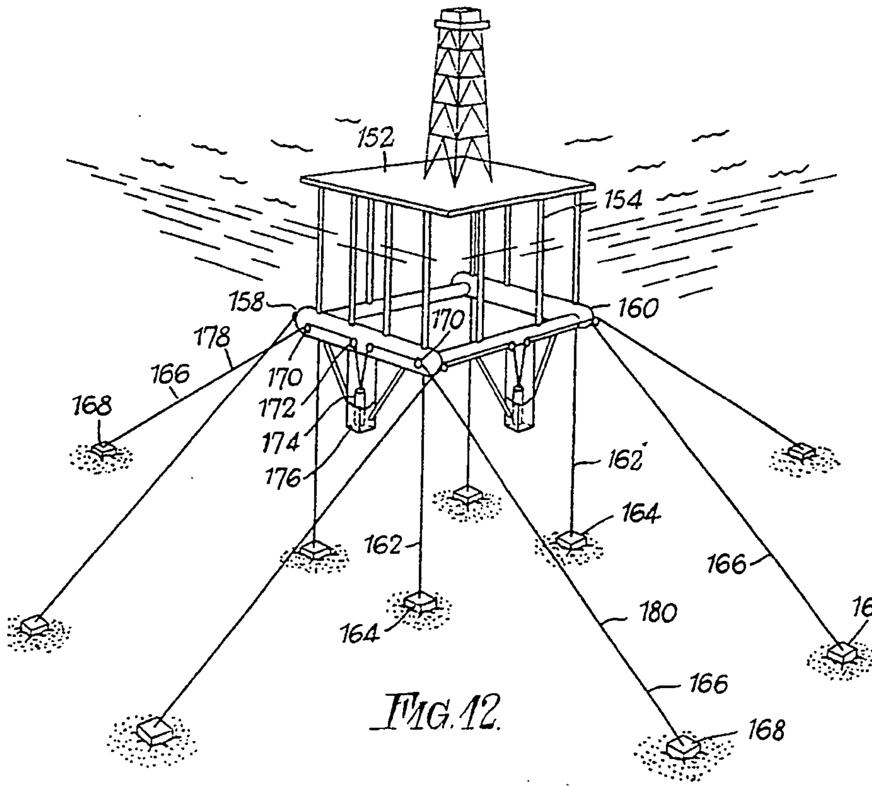


FIG. 12.

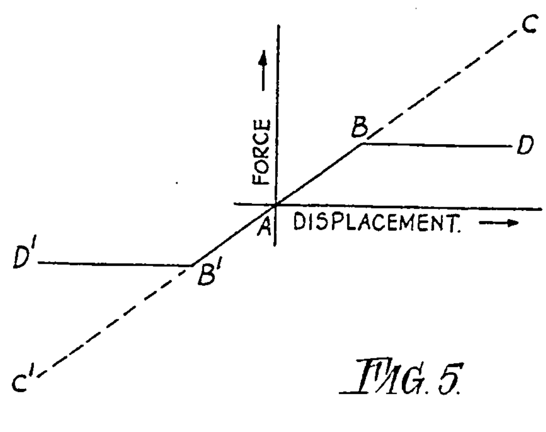


FIG. 5.

849,887 COMPLETE SPECIFICATION
4 SHEETS
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SHEETS 1 & 2

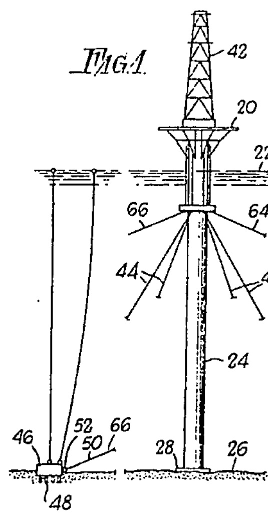


FIG. 1.

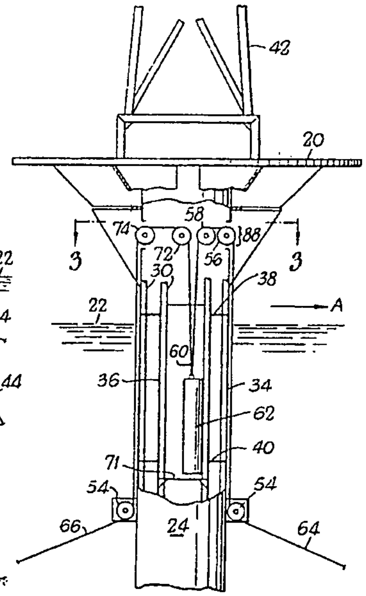


FIG. 2.

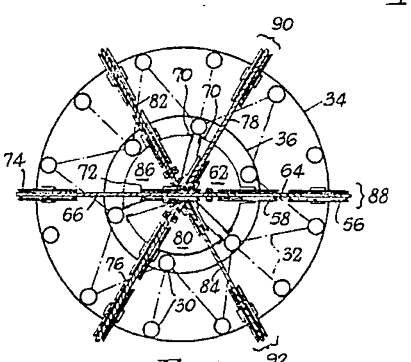
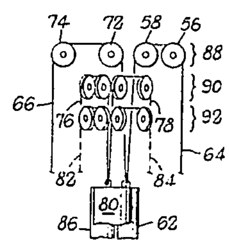


FIG. 3.



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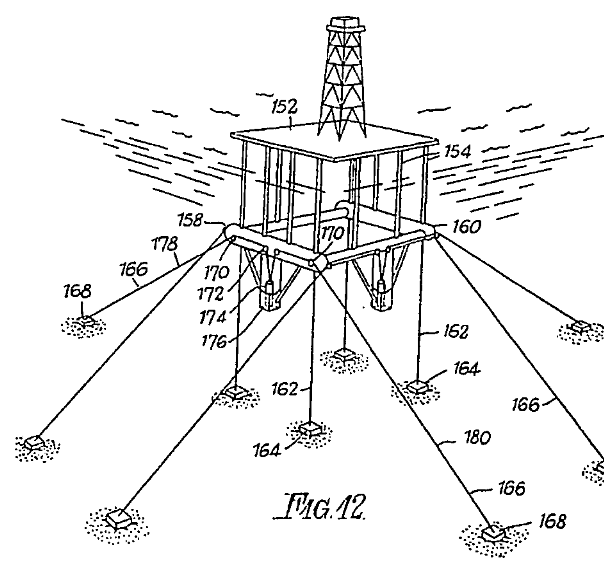

FIG. 12.

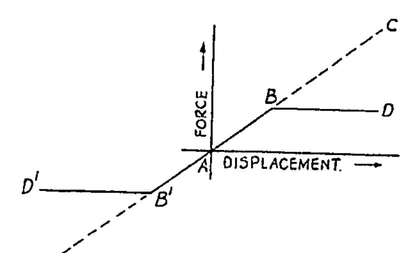

FIG. 5.

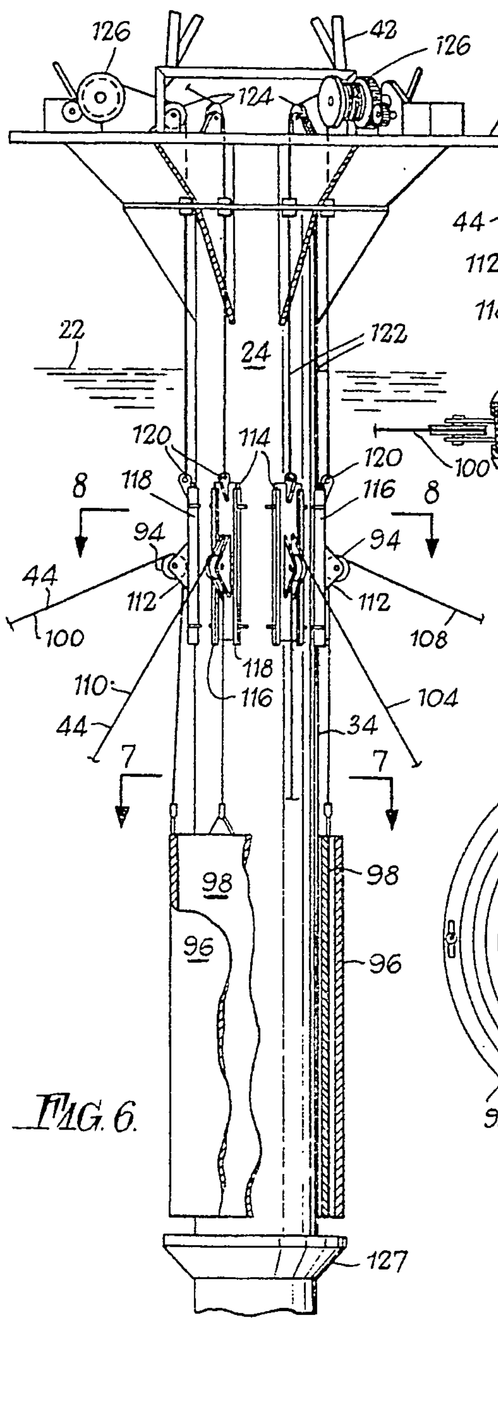

FIG. 6.

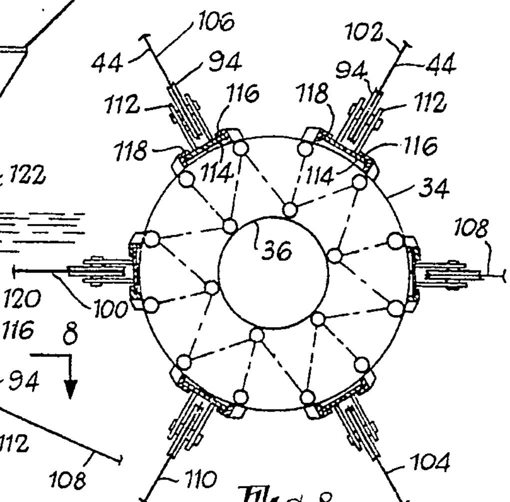

FIG. 8.

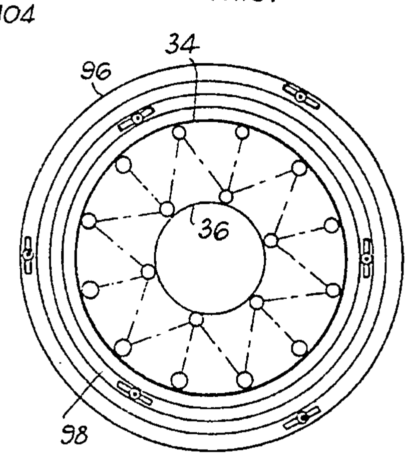

FIG. 7.

849,887 COMPLETE SPECIFICATION
4 SHEETS

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SHEETS 3 & 4

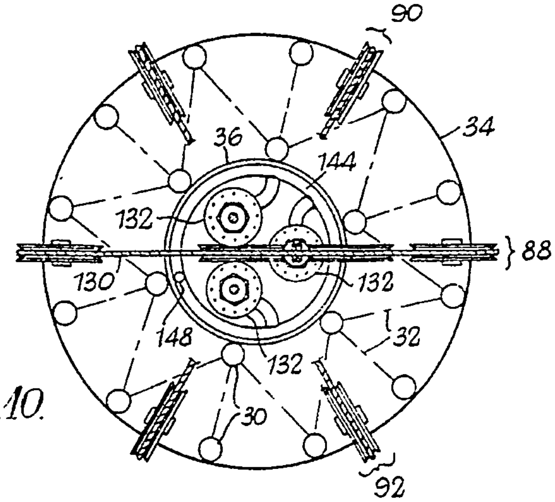
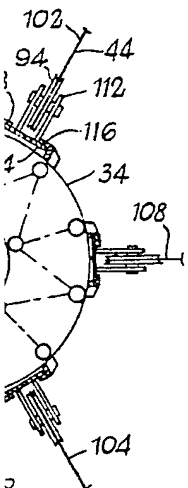
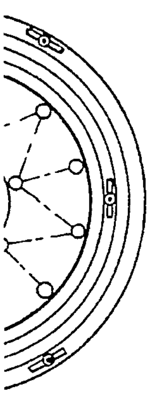


FIG.10.





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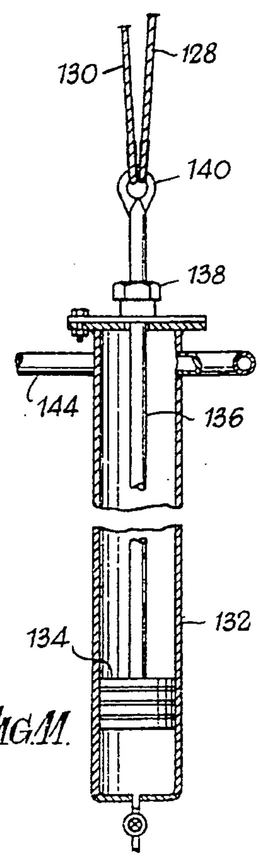

FIG.11.

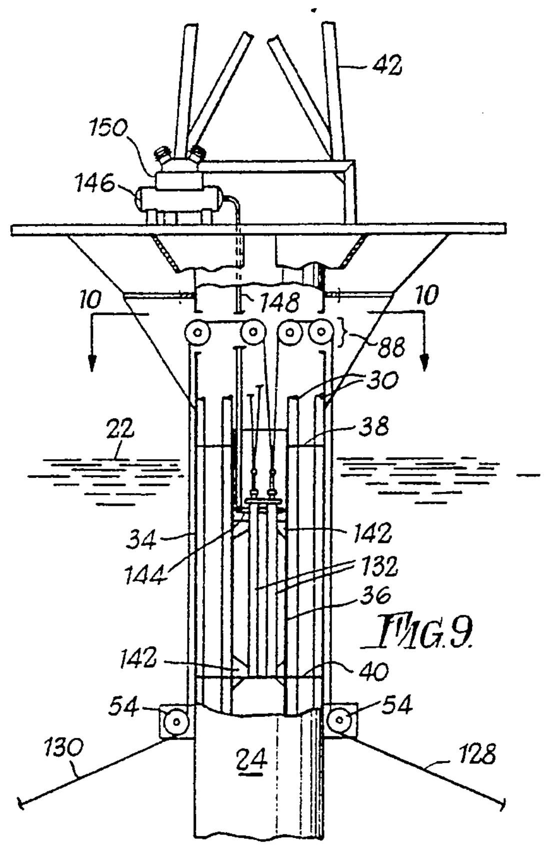

FIG.9.

849,887 COMPLETE SPECIFICATION
4 SHEETS
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SHEETS 3 & 4

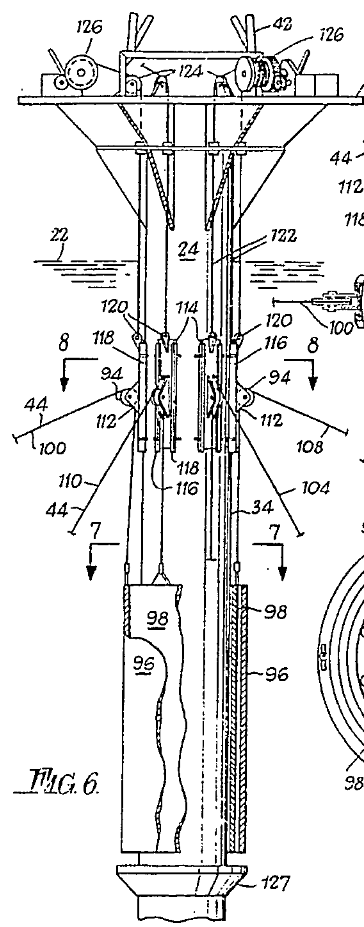
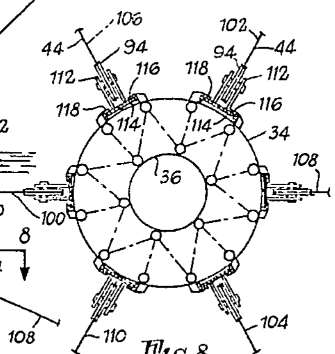


FIG. 6.



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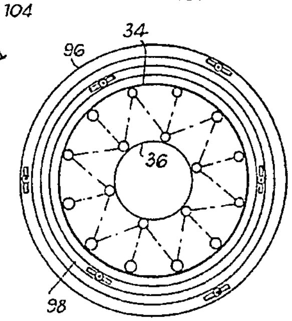

FIG. 7.

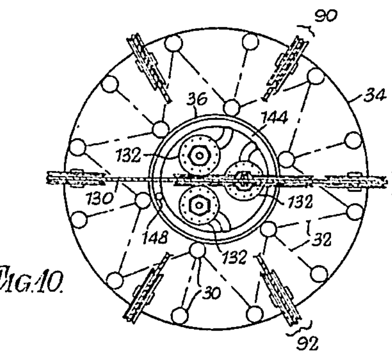

FIG. 10.

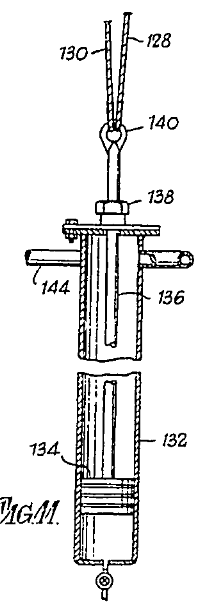

FIG. 11.

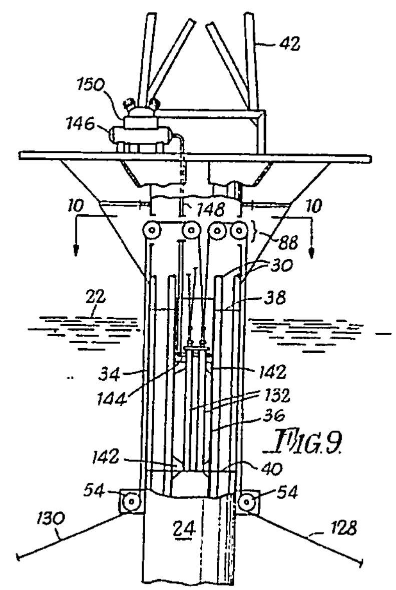

FIG. 9.